AC 2009-1875: INTERNATIONAL SERVICE-LEARNING PROJECTS FOR SENIOR CAPSTONE PROJECTS

Scott Reichle, Old Dominion University

Scott L. Reichle is an Assistant Professor in Civil Engineering Technology at Old Dominion University. His prior work experience includes work within the construction industry, engineering design and approximately 10 years as an attorney handling a wide range of matters including construction law. He has a B.S. in Civil Engineering from Virginia Tech, a M.S. in Civil Engineering from Old Dominion University and a Juris Doctor from Loyola Law School in New Orleans. He is also a registered Professional Engineer in the Commonwealth of Virginia.

Avery Bang, University of Colorado

Avery L. Bang is a Candidate for a M.S. in Civil Engineering for the University of Colorado at Boulder. She joined Bridges to Prosperity as the Director of Operations after leading a student team as project manager in 2007. She has industry experience in Structural Engineering and has international project experience in half dozen countries. She received her B.S. in Civil Engineering from the University of Iowa.

Carol Considine, Old Dominion University

Carol Considine is the Civil Engineering Technology Program Director and Associate Professor of Engineering Technology at Old Dominion University. She has over 15 years of industrial experience in the construction industry. She has a B.S. in Civil Engineering from Virginia Tech, and a M.S. in Civil Engineering from University of California, Berkeley. She is also a LEED AP.

International Service Learning Projects for Senior Capstone Projects

Abstract

Service learning is being adopted in many engineering programs at various course levels. International service learning experiences can provide senior level engineering students with opportunities to practice the required skills of engineering graduates as detailed by the ABET Criteria for Accrediting Engineering Programs. Bridges to Prosperity is a non-profit organization that builds footbridges in rural third world communities. These design build footbridge projects require a full year for fundraising, site visit, design and construction, and provide engineering students an opportunity to practice their knowledge of globalization, sustainability, engineering design, teamwork, and leadership. A team of students from the University of Iowa completed the design and construction of a footbridge in Peru in the spring of 2008. The planning, implementation and results of this service learning project are examined.

Project Background

Starting in 2006, a group of undergraduate civil engineering students from the University of Iowa undertook a service learning project to design and construct a footbridge as an augmented senior design project, satisfying a component of the department's required curriculum. The students were guided by the non-profit organization Bridges to Prosperity (B2P), based out of Yorktown, Virginia. Bridges to Prosperity is a volunteer based charity committed to empowering the impoverished in rural communities around the world through footbridge building and infrastructure capacitation programs.

B2P was established in 2001 by Ken Frantz. He was inspired by a photo in National Geographic Magazine of a broken bridge along the Blue Nile. Frantz traveled to Ethiopia to help repair the span. The experience of rebuilding the broken bridge and seeing first-hand the project's impact encouraged Frantz to continue. A simple footbridge can provide opportunities for remote communities through access to schools, clinics, jobs and markets. What started as a single bridge has expanded beyond building individual footbridges to include training communities, the development of an online library of sustainable standardized footbridge methods and designs, and providing volunteer field opportunities for corporate and academic teams, as well as individuals.[1]

Bridges to Prosperity matches academic teams with rural economically disadvantaged international communities to build pedestrian footbridges. These projects can be completed in one academic year and within an $18,000 budget, including both construction and travel costs. A typical project requires two trips in-country, the first of which sets the framework for the project. Community leaders are asked to form a Bridge Committee, allowing the academic team to negotiate a community participation agreement and establish a communication link. Great care is taken to ensure community buy-in to the project. The first trip also is used to complete a site-survey analysis used to design the bridge. A second trip, typically in late spring or early summer is taken to complete the construction of the footbridge. Although the construction takes nearly 10 weeks to complete, B2P personnel maintain constant contact with the academic team, local non-government organizations (NGOs) and the community such that construction per the teams' specifications begins prior to team arrival. This allows a team to be on-site during the critical stages of construction, typically accomplished within a two week timeframe.

The University of Iowa students branded their senior design team Continental Crossings and were given full responsibility for every aspect of the footbridge for the community of Yavina, Peru. Bridges to Prosperity offered coordination assistance to the students and partnered a local NGO with the student group to assist with logistics involved with material purchasing and transportation. The initial site selection and community meetings were also completed by B2P personnel to ensure community participation before student engagement. The site was selected in a rural community in Peru and in November of 2006, the team of students traveled to meet the community for which the bridge would be constructed. While there, Continental Crossings performed a preliminary site survey and worked with community leaders on aspects of the design that could be modified to best suit the community of Yavina. This participative approach to design ensured that the community would become fully committed to the project. By acknowledging the importance of community input, volunteer labor assignments were viewed by the community as an honor rather than a burden.

Preparations: As noted, the bridge crossing in Yavina, Peru was first presented to Continental Crossings by the non-profit organization Bridges to Prosperity ("B2P"). The organization has constructed footbridges in more than a dozen countries, with five previous crossings in Peru. Continental Crossings began the footbridge project by consulting B2P's online materials available to the public through their website.[2] These resources include design manuals that contain detailed information about the construction techniques and methods for both cable suspended and suspension bridges.

Continental Crossings also explored the possibility of using timber to construct the bridge in addition to cable bridges. Due to the questionable availability of materials and the assumption that timber would be less expensive than steel cable, preliminary research was completed to determine the design feasibility.

The students also researched indigenous bridge designs. The Incas constructed numerous simple suspension bridges over canyons and gorges to provide access for the Inca Empire. The bridges were made out of: 1) massive cables of woven ichu grass linking two pylons together; 2) two walkway cables; and, 3) an additional two cables, which acted as guardrails. The cable supported foot path was reinforced with plaited branches which made the bridges strong enough to even carry the Spaniards when they came and conquered the Incas while riding horses. Part of the strength and reliability of these bridges came from the fact that each cable was replaced annually by local community members who had the sole task of maintaining and repairing these crossings.

Site Survey: In November 2006, the Continental Crossings team traveled to Yavina, Peru to meet the community and to collect the data necessary for the project completion. Information was gathered on the hydraulics, geology, and topography of the site. While on site, the team investigated the needs and expectations of the community as well as determined the required bridge loadings and traffic volumes.

During the team's on-site visit, the availability of local materials was determined and local contacts were established to ensure the construction of the bridge could be facilitated across continents. One of the most common types of wood used in Peruvian timber constructions is Torino. The material properties of this wood were then researched and the local availability determined. Investigations were made into the availability of steel cable and what challenges would be posed by transportation. It was determined that the steel cable would have to be purchased in Lima and then transported by vehicle to the nearest point in the road. This transportation would take 2-3 days. Furthermore, the team met with the local mason of the region, who would be contracted by the team to lead construction of the bridge.

Community input was an integral aspect of Continental Crossing's preliminary efforts. During the initial trip to Yavina, the team held two main community meetings with the leaders. The people present consisted of Americo, a representative of the Peruvian nonprofit organization Ayuda en Accion, approximately 50 members of the local community including both men and women, and the Continental Crossings team. It quickly became apparent the main community concern was that a safe bridge would be constructed for children to use on their walk to and from school. The community also wanted a crossing that was structurally sound and could transport livestock, such as sheep.

The establishment of in-country contacts was necessary for progress to be made on the project while students were not on-site. Bridges to Prosperity's representative, Armando, informed Continental Crossings of the complications of working with unskilled local laborers and warned the team of conflicts that could arise. Armando also had the capacity to aid in the team's material selection, pricing, and location. On arrival in Cucso, the team met with Ayuda en Accion. Ayuda en Accion has been working in the region of Yavina for the past fourteen years and had the capacity to facilitate material transport and construction.

Bridge Design: Continental Crossings considered three alternatives during the preliminary design process. The design team analyzed the potential use of a timber truss bridge, a cable suspension bridge, as well as a cable suspended bridge. The design team considered a number of variables specific to the site when deciding upon the most economical and constructible bridge for their design.

Due to the lack of local carpenters, Continental Crossings chose to avoid a timber crossing that would require high level of skill for connection points. Following the decision to utilize steel cable, a comparative analysis was conducted between a suspension and suspended cable bridge. Quantities of cement were the first consideration. One of the main differences between the abutment designs is the size of the piers. The top of pier elevation necessary for a suspension bridge was approximately four meters. Alternatively, since the critical members in a suspended bridge run through the base of the pier rather than atop the pier, the suspended cable bridge required a pier elevation of only 1.5 meters from the top of the abutment. Therefore, it was determined that construction of a suspended bridge would be easier than construction of a suspension bridge and the suspended cable design alternative required a lower quantity of cement. Furthermore, based on preliminary calculations, a suspended bridge would require less steel cable than a suspension bridge for the relatively short span of 25 meters.

The suspended cable bridge was the design team's final selection for the crossing. Based on the preliminary calculations, the design team modified some of the typical specifications to lessen the dead-load weight of the bridge and to minimize material quantities to better suit the isolated location of the bridge site. The team designed the main load bearing cables to be the only two running across the base of the decking, allowing the top handrail cable to bear the weight of the suspenders and mesh wiring. The mesh wire was chosen as an alternative to the typical chained link fence in order to minimize the load and because the thin wire installation would require less time. The design team also verified the optimum tower height to be 1.5 meters. This relatively short tower height created a greater tension in the cable due to the low sag ratio of 5%, but in the case of this relatively light loading of 50 psf live load and 10 psf dead load, this design alternative was very feasible. The team also designed a simplified cable connection due to the nature of the non-load bearing cable railings.

Bridge Construction: The construction for the project was divided into three phases; Mobilization, Preliminary Construction and Final Construction.

The mobilization phase included material purchase, material transport, and community mobilization. Continental Crossings identified suppliers during their first trip and made arrangements for material purchase agreements during the months leading to their second trip. Community mobilization began following a preliminary construction meeting held between the Yavina community leaders and local volunteers. Preliminary construction could not begin without the purchase of materials; however, as mobilization was required throughout the entire project, the team tracked each task and phase on a project management chart.

The preliminary construction phase included all of the tasks to be completed prior to Continental Crossing's team second trip. This included site preparation, construction of foundations, tiers and towers and placement of a temporary crossing. Site preparation also included the collection of local sands and aggregate by the local community. Construction of the foundations, tiers and towers was led by a locally hired mason, organized by the team during their first trip. All labor for construction was donated by the local community, as detailed in the community agreement.

The final construction phase included construction of the anchors, installation and sag setting of cable and installation of decking. The walkway cable was installed first, wrapping the cable fully around the left abutment drum anchor, setting the sag from the right abutment anchor. The non-load bearing handrail cables on either side were affixed to u-shaped rebar fabricated into the tiers. Once the cable installation was complete, the installation of wood decking began. A simplified connection was designed by Continental Crossings, setting the pre-cut decking atop the walkway cables. Steel rebar suspenders attached the walkway and handrail cables, and acted as support for the fencing, the final component of construction. The Continental Crossings team members were on-site for 18 days and completed the bridge on schedule and under their initial material budget of $9,000.


Construction of right abutment ramp


Construction nears completion

Project Continuation: Continental Crossings identified project continuation as one of the main objectives for founding of the team. The team aimed to get the University of Iowa to introduce an international component into the Project Management Senior Design course, creating an avenue for future international projects. Other Universities including Colorado School of Mines, Michigan Technology Institute, and The University of Illinois have already begun to offer students the choice between the typical senior design project and an alternative for a developing community. Exposure to the entire design process matches recommendations for general engineering education, as suggested in the ASCE Body of Knowledge for the 21st Century and ABET, as indicated above. It also allows students the opportunity to provide humanitarian aid while gaining an invaluable international experience. Continental Crossings proposed that students at the University of Iowa's College of Engineering interested in pursuing this alternative should be given the option to do so through enrollment in the two semester course sequence of Design for the Developing World, followed by Project Management. Continental Crossings documented the entire process with the hope that another team could have the same opportunity while reflecting upon their teams' successes and failures.

Future projects have been implemented through a continued partnership with Bridges to Prosperity (B2P) and other universities including The University of Notre Dame, Arizona State University and The University of Southern California. The University of Iowa 2006-2007 Continental Crossings team was the first student design teams to participate in B2P's University Program. Following the completion of Continental Crossings' bridge, one of the students, Avery Bang, joined the B2P's Board of Directors to assist future B2P partnered University teams with similar bridge projects.

An Analysis of ABET Criterion 3 (a-k) as Related to the Project

Criterion 3 of the ABET accreditation system describes the program outcome requirements for graduating undergraduate students. These 11 requirements, typically referred to as ABET a-k, describe broad program outcomes including the skills, knowledge, abilities and understanding that students should possess upon completing an accredited program. This paper utilizes the 2008-2009 criterion for Engineering Programs. This being said, many of the requirements are the same or similar for Engineering Technology Programs. As a result, the analysis presented in this paper is equally relevant under Criterion 3 for Engineering Technology Programs[3].

Criterion 3. Program Outcomes:

Criterion 3a: Demonstrate the ability to apply knowledge of math, science and engineering.

It is noteworthy to consider that service learning projects constitute a problem-based learning methodology as well as cooperative learning techniques. Problem based learning has been widely recognized as a means of providing students greater insight into problems and, as a correlation, better development of problem solving skills.[4,5] Note that problem based learning can be utilized to address all of the ABET a-k requirements. With regards to ABET 3-a, the Continental Crossing students were able the apply their knowledge of math, science and engineering during the all stages of the project. Specific applications include the site survey, where the team gathered date on the site hydraulics, geology and topography of the site, research into the feasibility of alternate bridge designs, estimating project costs and scheduling of the project.

Criterion 3b: Demonstrate the ability to design and conduct experiments as well as analyze and interpret data.
This criterion is met with the data collection and analysis that was required as part of the site survey as mentioned above. In addition, the team's research and analysis of alternate bridge designs also demonstrates their skills for this criterion.

Criterion 3c and 3e: Criterion 3c requires students to demonstrate the ability to design a system, component or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability and sustainability. Criterion 3e requires students to demonstrate the ability to identify, formulate, and solve engineering problems**.**

These criterion are probably the most important when related to capstone design courses and this type of international service learning project provides ample opportunities for students to demonstrate that they can meet these requirements. This team identified the needs of the community and designed a footbridge to meet the community's needs of foot travel and livestock transport, with constraints of economics, social, safety, constructability and sustainability. Their negotiation of the community participation agreement to ensure they met the needs of the community and that the community fully supported and participated in the project is an excellent example of the socio-cultural aspects as they relate to project constraints. In addition, other project constraints included a limited budget ($18,000), the need to provide safe travel of children and livestock, need to design with materials that are easily transported to a remote site and a need to use sustainable materials. The team was able to complete their design within all of those constraints successfully.

Criterion 3d and 3g: Criterion 3d requires that students demonstrate an ability to function on multi-disciplinary teams and Criterion 3g requires that students demonstrate the ability to communicate effectively.

International service learning projects provide excellent opportunities for students to explore the working relationships among different disciplines that can make a project a success. The Continental Crossings team had to coordinate their project and work with two non-profits (B2P & Ayuda en Accion), community leaders, local community members, Peru subcontractors, and material suppliers. Learning to work across cultural and language barriers required to make an international design build project a success provides students a perspective that they are unable to gain in the classroom setting. It is not unusual for engineers to have to work with the client, financier, engineering subcontractors and constructors to build a successful project and students can get a glimpse of the relationships that must be built.

In order for the project to be successful, communications between parties, usually from a long distance, needed to be clear and easily understood. After the site survey, the Continental Crossing team returned to the US to design the footbridge. That design then had to be communicated to the both non-profits, the local community and the mason to ensure that bridge foundations were completed prior to the early summer arrival of the team to build the suspended cable portion of the bridge.

Criterion 3f: Demonstrate an understanding of the professional and ethical responsibility.

The use of an international service learning project requires students to go beyond the traditional ethics examples related to their specific project design and design decisions to include the recognition of and sensitivity to the socio-cultural aspects of their projects. Continental Crossing spent time with the community leaders to ensure that the community needs were met. The team modified the design to best suit the community to ensure community commitment to the project.

Criterion 3h, 3i and 3j: Criterion 3h requires that students demonstrate the broad education necessary to understand the impact of engineering solutions in the global, economic, environmental and societal context. Criterion 3i requires that students demonstrate the recognition for the need and an ability to engage in life-long learning and criterion 3j requires that students demonstrate knowledge of contemporary issues.

These ABET criterion address many of the other important aspects that go beyond just the ability to design a system or solve engineering problems. For example, 3i requires a recognition of the need for, and an ability to engage in lifelong learning. To instill in students the desire to engage in lifelong learning is arguably one of the more difficult aspects to incorporate into a program. To successfully instill this desire for continued learning four objectives must be addressed beyond the presentation of subject matter: 1) helping them to understand their own learning processes; 2) requiring them to take responsibility for their own learning; 3) creating at atmosphere that promotes confidence in their ability to succeed; and 4) helping them see education and school as personally relevant to their interest and goals.[6] The students in the Continental Crossing group were required to conduct a significant amount of independent research to successfully design and construct the project. This included web research, interviews and other sources as well. Assignments that require independent internet searches and literature searches promote a sense of independent responsibility for learning and also develop the skill to organize information in the absence of texts and course notes.[7] In the case of the Continental

Crossing team, not only did the students conduct independent research, the students further were required to conduct extensive planning and actual construction work independently. This places the students in positions of responsibility not typically seen in an academic setting, which further compounds this aspect of learning. In fact, the students themselves identified continuation of the project as one of the initial goals. Following completion of the construction, the group analyzed how similar projects could be utilized by their University in the future. Similarly, one of the students joined the Board of Directors for the Bridges to Prosperity non-profit organization so that she could have a continuing role in future projects. All of these actions support that the students had a desire for a continuation of the project and supported similar educations experiences for future students.

Likewise, the bridge building project instills ethical and social responsibilities and a respect for societal and global issues. Indeed, these are inherently addressed when students decide to take on a project that is designed to improve the lives of others living in another country. These positive aspects of service learning projects have been recognized by other in considering the ABET requirements and are difficult to refute.[8]

Criterion 3k: Demonstrate the ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.

Our global marketplace will demand that engineers are capable of working on international teams during their lifetime. An international capstone senior design project is an excellent opportunity to practice these skills using modern engineering tools. Continental Crossings did much of their research and communication via the internet. They produced sketches and drawings that were used by the community in Peru to complete the foundation construction prior to the team's arrival for suspended bridge construction. All of this information had to be transmitted to the community via the internet. In addition, the team developed their own website to document the project and to aid in their fundraising efforts.

Traditional engineering techniques, skills and tools were used throughout the project. Examples include: the initial site survey to gather hydrological, geological and site topographic data; use of scheduling programs for time and team management, computer programs for estimating and scheduling.

Assessment of Bridges to Prosperity Service Learning Project

An assessment survey, Figure 1, has been developed which will be given to all teams that participate in the Bridges to Prosperity Service Learning Projects. The results of the survey can be used to document that the participating students have gained the skills, knowledge, abilities and understanding that they should possess upon completing an accredited engineering program.

Bridges to Prosperity
Service Learning Assessment Survey

Project Name:
Team Name:
University Name:
Date:

Use the following rating scale for all survey questions:
1 – Strongly agree
2 - Agree
3 – Somewhat agree
4 – Somewhat disagree
5 - Disagree

ABET Criterion	Question	Rating Selection	Response/Comments
3a	I was able to utilize and apply knowledge of structural design during the project.		
	I was able to utilize and apply knowledge of estimating during the project.		
	I was able to utilize and apply knowledge of project scheduling during the project.		
3b	The bridges to prosperity project provided me an opportunity to analyze and interpret data.		
3c & 3e	I was required to consider and address economic issues during the project.		
	I was required to consider and address environmental issues during the project.		
	I was required to consider and address social issues during the project.		
	Working in a foreign county created unique social issues that I had to address.		
	I was required to consider and address political issues during the project.		
	Working in a foreign country created unique political issues that I had to address.		
	I was required to consider and address ethical issues during the project.		
	I was required to consider and address health and safety issues during the project.		
	I was required to consider and address manufacturability and sustainability issues during the project.		
3d & 3g	Effective coordination with community leaders and members was necessary for the construction of the bridge.		

	The project required coordination with the non-profit group, Bridges to Prosperity.		
	The project required effective coordination with material suppliers and local sub-contractors.		
	The project provided me with insight into how to work with others in a multi-disciplinary team.		
	The project required effective communication skills.		
	Language barriers required me to consider the importance of good communication.		
	Language barriers created unique communications issues.		
3f	The project required me to consider professional considerations.		
	The project provided me with insight into real-life issues of design professionals and construction managers.		
	The project required me to consider ethical issues.		
3h, 3i & 3j	The project had a positive economic impact on the community.		
	The project had a positive environmental impact on the community.		
	The project gave me insight into contemporary issues in the region.		
	As a result of the project, I have an interest in continuing volunteer or non-profit work.		
	My involvement in the project has increased my desire for life-long learning		
3k	The use of the internet and other technology was a key factor in the successful completion of the project.		
	The internet of great assistance with regards to communications with the region.		

Figure 1 – Bridges to Prosperity Service Learning Assessment Survey

Conclusion:

International capstone senior design projects expose students to a wide range of real-life engineering challenges from concept to implementation and provide excellent opportunities for engineering students. These projects enable students to use their engineering education to design and build structures that can benefit rural communities and at the same time they can gain a cultural sensitivity that will benefit them in their future careers. In addition, these projects aid in the demonstration that an engineering program meets or exceeds the ABET Criterion 3 a-k outcomes.

Bibliography

1. http://www.bridgestoprosperity.org/history.htm, accessed October 2, 2008.
2. http://www.bridgestoprosperity.org/bridgemanuals.htm, accessed January 28, 2009.
3. http://www.abet.org/accrediteac.asp, accessed January 28, 2009.
4. Woods, D.R., et al. 2000. The future of engineering education. Developing critical skills. Chemical Engineering Education. 34(2): 108–117.
5. Woods, D.R., et al. 1997. Developing problem-solving skills: The McMaster problem solving program. Journal of Engineering Education. 86(2): 75–91
6. Marra, R.M., K.Z. Camplese, and T.A. Litzinger. 1999. Lifelong learning: A preliminary look at the literature in view of EC 2000. Proceedings. 1999 Frontiers in Education Conference. Institute of Electrical and Electronics Engineers.
7. Felder, R.M., Brent, R., Designing and Teaching Courses to Satisfy the ABET Engineering Criteria., 2003, Journal of Engineering Education, 14.
8. Phillips, L., Brady, A. and Jousma, K., Interdisciplinary International Senior Design: How Service Learning Projects in Developing Countries Support ABET Accreditation, ASEE Conference, AC 2007-1638.